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ABSTRACT

An engineering technique invented in the 1920s remains unused by most engineers today because their instructors are unaware that software applications have simplified the exceedingly complex calculations required. The technique is called the design of experiments (DOE), a method that optimizes products and processes. This process outshines one-factor-at-a-time (OFAT) experimentation because OFAT is incredibly cost- and time-prohibitive. Many engineering professors remain unaware of how effective DOE is because they are also not familiar with the technique. Consequently, engineering students in most colleges continue to be taught slow and costly OFAT experimentation. Now, however, personal computers make DOE easy to use because software performs the complicated calculations. (CCM)

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"WHAT THEY DON'T TEACH YOU IN ENGINEERING SCHOOL."

BY

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WHAT THEY DON'T TEACH YOU IN ENGINEERING SCHOOL.

by

Rich Burnham

A statistical design method invented in the 1920's -- capable of dollar savings equal to 20% of a company's sales -- remains unused by almost 90% of engineers today. And according to Mark Anderson, principal at Stat-Ease, Inc. (Minneapolis, Minn.), it's an alarming oversight. He says, "It's easy to think that a quality control technique almost 80 years old can't possibly be of interest to anyone today. The truth is, however, today's engineering professors simply have not themselves been taught the method."

The method Anderson refers to is design of experiments, or DOE. DOE is an ideal method for optimizing processes and products, but perhaps as few as 10% of engineers, experimenters, and researchers today are using it. By doing so, they are discovering product and process breakthroughs often considered impossible. Here are a few examples:

- Eastman Kodak saves $200,000 by discovering that retooling an existing

machine, instead of purchasing a new one, meets the production needs of a critical light-sealing photo clip. Set-up time decreases dramatically from eight hours to only 20 minutes. Scrap is reduced by a factor of 10. Repeatability increases to 100%.

- John Deere Engine Works enjoys phenomenal savings of $500,000 annually. The reason: a costly process, chromate conversion, is found to be unnecessary for paint adhesion.
- Puritan-Bennett Aero Systems, a manufacturer of pelletized oxygen generators used in oxygen masks, begins producing their most reliable emergency breathing devices in history -- while lowering production costs. Product development time is slashed to 1.5 weeks rather than the typical several months.

Design of experiments, discovered in the 1920's by British statistician Ronald Fisher, revealed to experimenters a new way of creating and designing products and formulations. Until Fisher's time, engineers often hunted in vain for ideal designs by testing just one factor at a time (OFAT) - a laborious and expensive technique. (Ironically, the majority of engineers today continue to use the same type of antiquated OFAT testing.)

"The problem with OFAT," says Stat-Ease's Anderson, "is it's tremendously cost- and time-prohibitive. OFAT testing requires an entire experimental cycle when considering only one factor at a time. And because each experimental run considers only one factor, many runs are needed to get sufficient information about the set of conditions contributing to a problem."

On the other hand, DOE's systematic approach to experimentation considers all factors simultaneously, not just one factor at a time. By revealing how interconnected factors respond over wide ranges (without the need to directly test each possible value) DOE increases productivity and decreases costs. It minimizes the number

of experimental data points needed to reach conclusions about a process or formulation.

Unfortunately, engineering students in most colleges today continue to be taught slow and expensive OFAT experimentation methods instead of solution-rich DOE techniques. They simply aren't being exposed to the power and simplicity of design of experiments. Their instructors aren't aware how DOE software simplifies a process.

When DOE was first invented, there was a valid reason why it wasn't taught in engineering schools --calculations required for DOE analysis are excruciatingly complex. It wasn't until almost seven decades later, when desktop PC's and reasonably priced DOE software appeared, that DOE became accessible to experimenters.

John Guerin, Ph.D., is president of Turning Points Management Consulting. Because he uses DOE to improve product quality, he believes the future of DOE is important. "There is a new emphasis on quality," he explains. "I've looked at DOE from both sides -- as a technical person and as a business manager." Using a

computer to perform DOE removes the drudgery, allowing the researchers to spend time interpreting results rather than analyzing them. "When I started out, the analysis took as long as doing the experiment," he explains. "It wasn't really very practical."

Douglas Montgomery, Ph.D., is a professor of engineering at Arizona State University's College of Engineering, as well as the author of *Design and Analysis of Experiments*. He notes that professors and students alike are gradually gaining an understanding of the importance of teaching DOE in the classroom. "The engineering faculty have discovered that their students need to know this," he says. "The way they usually discover this is by going out and spending some time in the real world." In the real world, Montgomery explains, American companies need to train their engineers to use DOE in order to be competitive. He firmly believes DOE is a necessary component of future engineering courses.

"If engineering faculty learn anything about what their students do when they graduate," states Dr. Montgomery, "they'll discover that engineers use statistical concepts

and statistical thinking. They need to design experiments from a statistical viewpoint."

While DOE is slowly becoming a standard engineering course, private DOE training and software companies like Stat-Ease continue conducting workshops. DOE workshop graduate Doug Stohr is representative of a DOE user who learned the method after he finished college. As engineering manager for Taber Bushnell, Inc., (Minneapolis, Minn.), Stohr recognizes the necessity of DOE and DOE training. He says, "DOE allows me to take my knowledge of statistics, upgrade it, and apply DOE tools. We use a DOE software tool called Design-Expert®."

Many firms now specialize in DOE software and training. Nation-wide workshops frequently provide attendees with 3-1/2 days of DOE training, providing a good mixture of theory and application. Topics include simple comparative experiments, analysis of variance, screening designs, and response transformations.

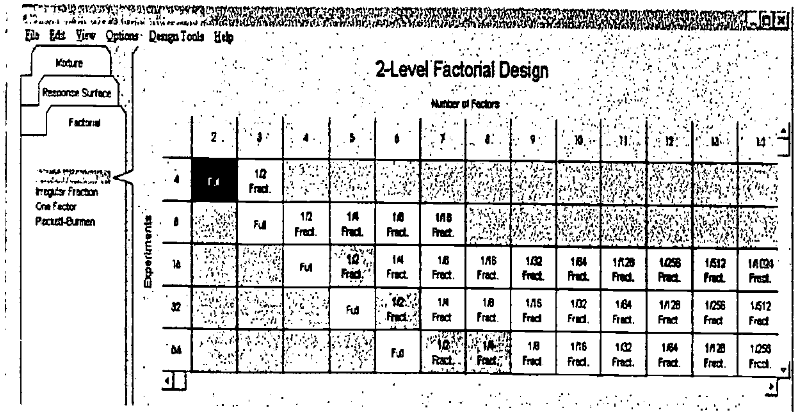
Bruce Ankenman, assistant professor in the Department of Industrial Engineering at Northwestern University, is

pushing to have DOE taught in a variety of engineering disciplines. Professors need to recognize its value in order to make the effort to integrate it into their classes. "This is what engineers do," states Mr. Ankenman. "Engineers run experiments. And DOE makes the quality of the conclusions better." He stresses that because of an engineering student's full schedule, professors are more apt to work DOE material into existing courses rather than adding new courses.

Professors and engineers value DOE because of what they encounter in the real world. They see firsthand the importance of this method. Experimenting in a planned manner -- with all variables simultaneously acting and reacting -- ensures accurate results, dramatic cost savings, and impressive quality improvements. Stat-Ease's Mark Anderson says, "In today's extremely competitive environment, engineers can no longer afford to experiment in a trial-and-error manner, changing one factor at a time. For today's complex manufacturing problems, you need much more. DOE reveals the solutions."

INSERT IMAGE OF DESIGN BUILDER SCREEN SHOT.

SCREEN SHOT COURTESY STAT-EASE, INC.



SUGGESTED CAPTION: SOFTWARE TOOLS SUCH AS DESIGN BUILDER FROM STAT-EASE INC'S DESIGN-EXPERT® DRAMATICALLY SIMPLIFY DESIGN OF EXPERIMENTS. COLOR-CODING SIMILAR TO A STOPLIGHT REPRESENTS SAFE, CAUTIOUS, AND RISKY DESIGN OPTIONS.

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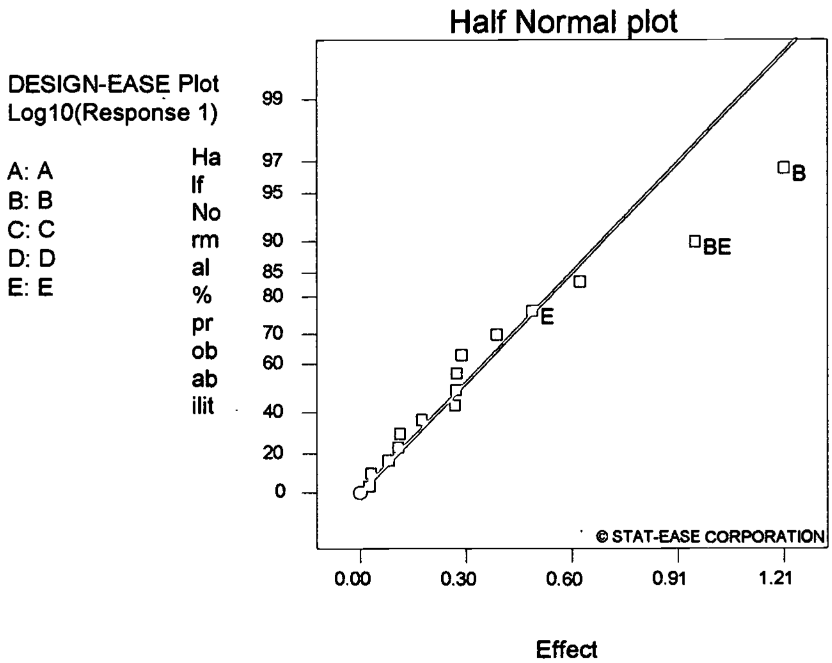

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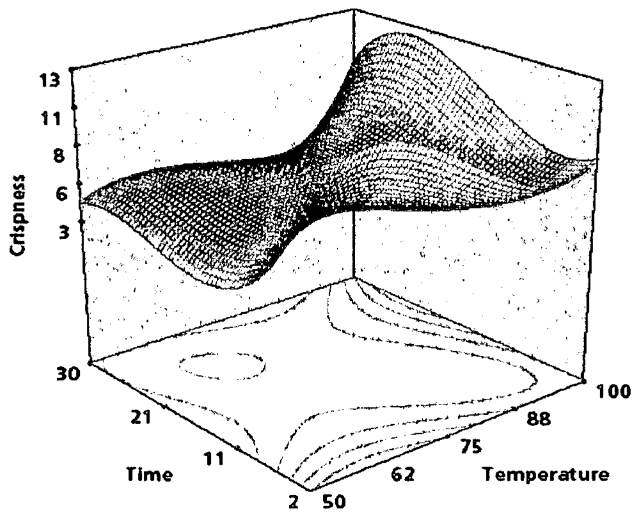

SUGGESTED CAPTION – RESPONSE SURFACE METHODOLOGY (RSM) PLOTS IDENTIFY PEAK PERFORMANCE "SWEET SPOTS." THIS VIEW SHOWS BOTH 3-D(UPPER SHAPE) AND2-D (CONTOUR LINES AT BASE OF GRAPH).

Design of Experiments: A Definition

[EDITOR -- Sidebar, perhaps?]

Design of experiments, abbreviated DOE, provides information about how factors such as time, temperature, and chemistry, for example, interact in a system. DOE simultaneously evaluates multiple factors within a process or product, making it a useful tool for engineers.

DOE is superior to traditional one-factor-at-a-time (OFAT) experimentation because OFAT needs many runs to obtain the equivalent knowledge of a process. Additionally, OFAT cannot reveal interactions.

Although DOE was invented in the 1920s, it remained unused because it required laborious hand calculations. Today, DOE software easily sets up and analyzes statistically sound DOEs. It does this by fitting data into mathematical equations and predicting outcomes for any combination of values.

Consequently, engineers, scientists, and researchers are optimizing responses and discovering winning combinations.

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